1. Introduction
The seabed of the Dutch part of the North Sea mainly consists of fine to medium sands which are deposited during the Holocene. The morphology of the Dutch Continental Shelf (NCP) shows distinct morphological units as: a deeper basin in the north, tidal sand banks, shore face connected ridges, long shore bars and sand wave fields (see figure 1 bathymetric map with commonly used names).

Figure 1 Study area the Dutch Continental Shelf with frequently used names plotted on the bathymetry.
Sand waves are large scale bed forms with a wave length of 100 – 800 m and a height of 1 – 12 m. Sand waves occur there where besides the availability of sand (median grain size of 0.25 – 0.35 mm) the current velocities are greater
than 65 cm/s. The sand waves are symmetric or asymmetric depending on the
direction of the net-tidal sand transport. Coarser grains can be found on the
crests while finer grains can be found in the troughs (Passchier & Kleinhans,
2005; Vries, 1997).

By studying the bathymetric and bathymetric position index (BPI) of the NCP it
attracts attention that there are varying sand wave heights on the NCP. The
sandwave height as used in this paper is the height difference between crest and
trough on a perpendicular transect as shown in figure 2a+b.

![Figure 2a showing the location of the profile on the bathymetry, b) the depth profile showing sand waves in the range of 2-4 m (from crest to trough).]

The aim of this study is to computerize a sand wave height map of the Dutch
Continental Platform (NCP). This is done by determining bathymetric ranges on
the NCP for varying neighborhood ranges. The bathymetric range maps are
validated by comparing depth profiles and bathymetric range profiles.

2. Datasets and methodology

During this study we used the bathymetric dataset of the NCP. The dataset
covers the entire NCP and is a raster with grid cell sizes of 200 x 200 m. The
bathymetric map is based on an interpolation of several sub datasets. The sub
datasets are soundings from the Dutch Hydrographical service and the Dutch
Navy. For each area the most recent sounding has been used. For the soundings
the datum is the average Low Low Water Springtide level in 5 years.

In ArcGis there are functions available to determine the maximum range in a
neighborhood for each separate cell. If the range function is applied on a
bathymetric map the output would be a map showing the range of depths for the
given neighborhood. In an area with varying water depths ranges are greater
than in an area with small variations in water depths.

![Figure 3 Determination of different neighborhoods]
It is possible to determine different neighborhoods as shown in figure 3 and thereby it is also possible to determine different sizes for the areas. In this study the circle neighborhood was chosen with a varying radius of 1-4 cells. While a cell has a size of 200x200m the maximum neighborhood has a maximum diameter of 1600m.

3. Results bathymetric range map of the Dutch Continental Shelf
The final bathymetric range map of the NCP is shown in figure 4. The colors scheme for the legend is chosen as follows: blue colors represent small bathymetric ranges whereas dark brown colors are larger ranges. In the north the Oyster Grounds (deeper basin <-35 m) is visible as an area with small ranges (0-1 m). West of the Oyster Grounds the Claever bank can be identified as an area with ranges greater than 15 m. The distinct difference in ranges in this area is due to the morphological development of this area. During the last glacial period the North sea was dry (+- 9000 BP the coastline layed north of the Doggersbank). During this last glacial period rivers were active on the Northsea bed, leaving the distinct morphology behind.
On the bathymetric range map one can find morphological features which are typical for shallow seas. Two sand wave fields are visible, one north of the barrier island Texel and a bigger sand wave field in the southern part of the NCP. Height differences in the northern sand wave field are in the range of 5-6 m while in the southern part bathymetric ranges are up to 15 m. Tidal ridges (bathymetric ranges up to 15 m) can be identified in the central part of the NCP and shore face connected ridges (bathymetric ranges up to 15 m) north of the barrier island and west of the province Zeeland.
Figure 3 Bathymetric range map of the NCP with a circle with radius 2 cells.
4. Validation of the bathymetric range map by comparing maps with different neighborhoods (1-4 cells) and two profiles

The 4 bathymetric range maps are validated by comparing two bathymetric profiles with profiles showing the bathymetric range. While this study focuses on the amplitude of sand waves the location of the depth profiles are chosen in the southwestern sand wave field shown on the bathymetry (figure 5). To get insight in the spatial distribution of bathymetric ranges due to varying cell sizes four bathymetric range maps of the southern sand wave field were generated with circle neighborhoods in the range of 1-4 cells.

Figure 5 Locations of profiles A-A' and B-B' on the bathymetric map.
Figure 6 profiles A-A’ a) showing bottom profile (m), b) bathymetric range (m) with circle neighborhood with 1 cell, c) bathymetric range (m) with circle neighborhood with 2 cells, d) bathymetric range (m) with circle neighborhood with 3 cells, e) bathymetric range (m) with circle neighborhood with 4 cells.
Figure 6 profiles B-B' a) showing bottom profile (m), b) bathymetric range (m) with circle neighborhood with 1 cell, c) bathymetric range (m) with circle neighborhood with 2 cells, d) bathymetric range (m) with circle neighborhood with 3 cells, e) bathymetric range (m) with circle neighborhood with 4 cells.
Figure 7 a) bathymetric range with a neighborhood circle and a 1 cell range, b) bathymetric range with a neighborhood circle and a 2 cell range, c) bathymetric range with a neighborhood circle and a 3 cell range, d) bathymetric range with a neighborhood circle and a 4 cell range
4. Discussion

Accuracy of the method

The bathymetric profile (figure 5 a) shows part of the sand wave morphology in the south western part of the NCP. At 2.5 km one can see a peak of about 8 m height difference. This peak corresponds best with the bathymetric range with a neighborhood with a circle range of 2 cells (figure 5 c). At 10 km one can see a peak of about 10 m height difference. This peak corresponds best with the bathymetric range with a neighborhood with a circle range of 2 cells (figure 5c).

Profile B-B`

There are two inaccuracies determined that may arise by using this method. When sand waves have broad crests, broader than the range that is set, the resulting sand wave height would be determined as 0. Another inaccuracy that may occur is when sand waves are super imposed on crest of tidal ridges (see for example figure 9). Due to the set range the values would be in the range from the trough of the tidal ridge to the crest of the tidal ridge. When sand wave heights are determined on these super imposed sand wave locations, values would be in the range from tidal ridge crest to the trough which is not a representation of reality.

5. Conclusions

The bathymetric range map shows the sand wave height differences on the NCP. The bathymetric range map with a circle neighborhood with 2 cells is the best map to show the amplitude of the sand waves. Inaccuracies may occur when sand wave crests are broader than the range which is set to determine the neighborhood which results in sand wave heights 0. When sand waves are superimposed on tidal ridges, determined sand wave heights with this are incorrect. This is due to the range from the superimposed sand wave on the tidal ridge crest to the trough of the tidal ridge.

References
